Designing Undergraduate Research Experiences for Non-traditional Student Learning at Sea

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Abstract
The primary goal of the experiential learning model that forms the basis of the environmental science curriculum at University of Washington, Tacoma (UWT) is to enhance undergraduate education by involving students in ongoing relevant research projects that extend beyond the classroom into the broader scientific community. To do this it is imperative to minimize costs while providing student access and ensuring data quality so that this data may be used for scientific purposes. During the summers of 2001 and 2002, undergraduate students from UWT participated in two very different marine research courses designed by environmental science faculty. We compare these two educational models and discuss the pros and cons of each.

Introduction
The lives of those people living within Puget Sound and the Georgia Basin are intimately entwined, economically and socially, with the coastal waters of the Pacific Northwest. However, despite the importance of these waters to the livelihood of the region's population, few learning opportunities exist that create an incentive for local undergraduate students to study Pacific Northwest oceanography. Many of the opportunities that do exist are tailored to traditional, full-time college students who do not work and have no children or families to care for. Therefore, the non-traditional student population is usually left out when it comes to oceanographic research.

The University of Washington, Tacoma (UWT), a two-year, upper-division, primarily undergraduate institution, serves a non-traditional student body. As a result of the organizational structure of Washington state's educational system, most of UWT's incoming students come from the state's community colleges, where access to inquiry-based learning experiences through undergraduate research opportunities in the sciences are severely limited or nonexistent. Science education forums regularly reiterate that undergraduate research experiences are invaluable for truly engaging undergraduate students in the excitement of science and necessary for adequately preparing these students for science-related careers or graduate programs (Sigma Xi1989; Sigma Xi 2000; Taylor and Barnard 1980; Tobias 1992; Wenzel and Austin 2001). Moreover, access to scientific research opportunities is especially important in educating the non-traditional students UWT serves (Secord and Greengrove 2002; Tobias 1990). Given that the University's physical location offers a wonderful array of undergraduate research possibilities related to the oceanography of Puget Sound and the Pacific Northwest coast, we have experimented with different models for offering undergraduate oceanography research experiences to our non-traditional student body at sea.

Environmental Science Model at UWT
UWT was founded by the State of Washington in 1990 as one of five new statewide, upper-division undergraduate institutions, with the intention that these institutions would address the real need for student access to a four-year Bachelor's degree in the state. UWT is a commuter campus, and as such serves the place-bound, time-bound residents of the South Puget Sound region, 83% of whom come to UWT from community colleges in the region. The University student population has an average age of 31 and 69% of its students are women. More than 50% of the student's work 20 or more hours per week, 61% receive some form of financial assistance, and 59% of them are the first members of their families to attend college. For most of its students, UWT represents the only opportunity for an advanced undergraduate science education.

The physical and biological sciences at UWT are housed within the Interdisciplinary Arts and Sciences (IAS) Program, which produces more than half of the student credit hours at the University. As an "interdisciplinary" program, IAS requires that all students take at least one science course, and all the sciences are organized within a framework of one environmental science curriculum (Secord and Greengrove 2002). Therefore, the environmental sciences program at UWT serves as the only gateway for undergraduates interested in science and science-related careers. This program follows national models in incorporating an interdisciplinary approach to the study of environmental science that includes not only the technical and quantitative aspects but also the larger societal context that impacts the role that science plays in addressing environmental problems (Archie 1996; Hungerford and Peyton 1986; Simmons 1994; UNESCO 1995; Weis 1990; Weis et al. 1992; Wilke 1995).

From its inception in 1996, the environmental sciences program has been built upon the premise that inquiry-based learning is the most effective means of educating and retaining non-traditional students in the sciences (Secord and Greengrove 2002; Shiber 1999; Tobias 1990). As a result almost every science course taught here, for majors and non-majors alike, offers students the opportunity to participate in hands-on laboratory and field-based activities (Secord and Greengrove 2002). This commitment to inquiry-based, hands-on science education has not only helped retain science majors, but it has also inspired non-science students to pursue one of the environmental science degrees offered at UWT. Therefore, our goal of expanding undergraduate research opportunities through field-based oceanography is a natural extension of our existing environmental science curriculum (Greengrove and Secord 2003).

Serving Non-Traditional Undergraduate Students

Currently, opportunities for undergraduate involvement in oceanography at sea are primarily limited to piggybacking on faculty-based research cruises, floating classrooms on large cruise ships, and seagoing programs run by private organizations. Floating classrooms on large cruise ships (e.g. University of Pittsburgh's Semester at Sea), while getting numerous students out to sea, actually offer little in the way of hands-on oceanography. Participation in a faculty research cruise does introduce students to real oceanographic data collection, but these cruises are not specifically designed for undergraduate learning and often allow only limited student involvement. On the other hand, privately run oceanography programs (e.g. SEA's Sea Semester) are specifically designed for undergraduates, but unfortunately these programs are often too long and expensive to be viable for the majority of UWT's non-traditional students.

Therefore, UWT has experimented with approaches differing from those above in order to create an undergraduate-oriented oceanographic research experience that is designed to allow our non-traditional students to participate (Greengrove and Secord 2003). This has required that we minimize costs and keep ship time to less than two weeks. Over two summers we have had the opportunity to test two very different course models, and as a result we have gained valuable insights into how a successful non-traditional undergraduate experience at sea can be achieved. This paper compares and contrasts the two summer course designs and qualitatively assesses the pros and cons of each with regard to undergraduate student learning.

Course Design and Teaching Methods

The oceanography course, "Research at Sea" (TESC 439), was taught during the summers of 2001 and 2002 by two UWT environmental science faculty members—a physical oceanographer and an environmental chemist. In order to make it possible for any UWT student—rather than just environmental science majors—to fully participate in the research cruise, it was necessary to cover introductory oceanography prior to the start of each cruise. This was done as a two-step process:

1. A general Pacific Northwest history and oceanography course was developed for spring quarter to provide students with basic background material.
2. Immediately before going to sea in the summer, students learned the practical oceanography applications needed as preparation for what they would be doing at sea.

Onshore Instruction

This interdisciplinary, 5-credit pre-requisite course, titled "Maritime History and Science in the Pacific Northwest" (TESC 347), covered introductory oceanography within the broader context of the natural resource history of the region. This treatment engaged both science and non-science students alike by connecting regional applications of basic oceanography concepts to cultural, economic, and literary historical events in the Pacific Northwest. For example, the physical and chemical bases for biological productivity in Puget Sound and along the Northwest coast of the U.S. were used to explain the historical formation of wide-ranging indigenous economies and cultural practices, as well as the allure of natural resource extraction for early European and American settlers and modern corporations. The combination of traditional oceanography with subjects normally relegated to the humanities and social sciences was instrumental in enticing many of the non-science students to also participate in the summer course. To fulfill university requirements, this spring quarter course was open to a large number of UWT students, many more than could take part in the summer course, with places reserved for those few already committed to continuing in the summer course. Therefore, a large number of those taking this course were not originally intending to enroll in the summer.

Both in 2001 and 2002, the summer "Research at Sea" course began with three weeks of intensive shore-based instruction. This shore component included library research and experimental design for onboard group project work, an introduction to oceanographic instrumentation and data analysis, basic navigation and charting techniques, and information sessions designed to prepare students for the logistics of the cruise. Students were divided into research groups at the beginning of the onshore portion of the course, which allowed the groups time to get to know each other and share information garnered for their projects. Groups were chosen by professors so as to equally distribute student skills as best as possible. Characteristics considered in forming groups included science background, data analysis and graphing familiarity, physical abilities necessary for sailing a tall ship, leadership potential, and interpersonal skills. Group projects were kept relatively straightforward and were organized as general summaries of chemical, physical, and biological oceanography. Onboard the ship and upon return to Tacoma, the groups synthesized the data collected and each team produced a scientific paper, presenting their results in a mini-research symposium shortly after each cruise.

In addition to the scientific group assignments, students were also required to keep personal journals for the duration of the cruise. Students were encouraged to write whatever they wanted and journals were only collected for a cursory check at the end of the course, without reading any of the content. However, students then used this journal as the basis for a creative writing piece that was submitted as a required part of their grade. Students were introduced briefly to various ideas for making journal entries more insightful and meaningful, and provided with downtime to write in their journals. Methods for accomplishing this were provided by the UWT writing faculty.

Figure 1. The RV *Clifford A. Barnes*, during the 2001 undergraduate cruise.

Puget Sound Cruise: Summer 2001

The first year the design of the 10-credit summer course was somewhat thrust upon us at the last minute. Construction of what was to be our ship, which would carry 20 students from Tacoma, Washington, to Portland, Oregon, was not completed on time, our contract was cancelled with less than a month's notice, and we were forced to find an alternative. Fortunately, we were able to secure the RV *Clifford A. Barnes* (Figure 1) for a weeklong cruise. This unplanned change has had the unforeseen advantage of allowing us to compare and contrast two very different cruise designs. As the 60 ft. *Barnes* was not intended for open ocean work, we constrained our cruise to the relatively protected waters of Puget Sound and the eastern portion of the Strait of Juan de Fuca (Figure 2). In addition, this ship only sleeps six passengers, and as we had seven students and two professors we were forced to dock or anchor and send a professor and two students ashore to sleep each night in a campground or motel.

The *Barnes*, a research vessel owned by the University of Washington, was outfitted with a real-time CTD and bottle carousel (SBE 25) on a hydraulic winch, which was also used to collect sediment samples using a VanVeen surface dredge. The CTD was additionally equipped with a fluorometer and a dissolved oxygen probe. Other onboard instrumentation was brought from UWT or rented from the UW School of Oceanography and placed in the small lab adjacent to the back deck. This included dissecting and compound microscopes for plankton identification and enumeration, an autotitrator for dissolved oxygen determination, a field spectrophotometer with flow-through assembly (Hach Co. DR/2010) for onboard nutrient analyses (nitrate, nitrite, phosphate, and silica), and a full chlorophyll setup (vacuum manifold, sonicator, centrifuge, and fluorometer). Zooplankton and phytoplankton samples were collected by hand hauling nets over a 30 ft. vertical tow. Computer availability was limited to two laptops used between meals on the galley table.

Two research groups were formed such that each team had at least three members. All students and faculty worked together the entire day so that interaction was constant among all participants, with the exception of late nights and early mornings due to sleeping arrangements. Since piloting, navigation, and shipboard chores were performed almost entirely by the ship's captain and mate, on average students spent around 12-16 hours per day were spent on sampling, analysis, and data interpretation.

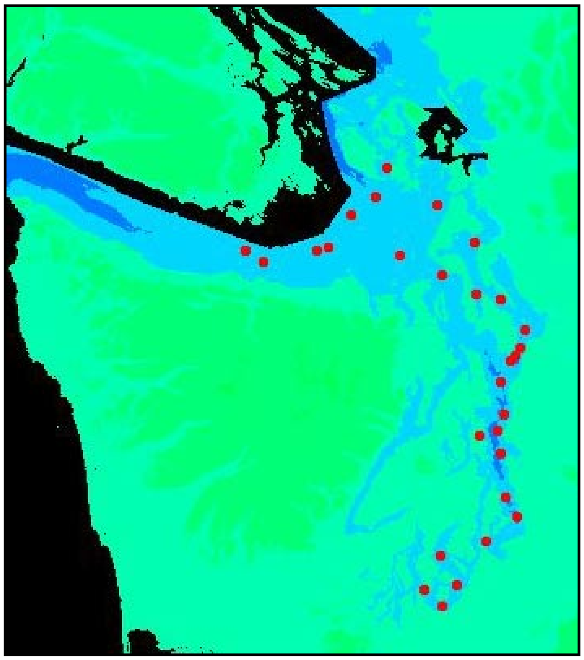

Figure 2. Sampling stations for the 2001 research cruise. The cruise track included the Strait of Juan de Fuca and the Main Basin, Whidbey Basin, and South Basin of Puget Sound.

Figure 3. The SSV *Robert C. Seamans*, chartered for the 2002 undergraduate cruise (Photo courtesy of SEA).

Pacific Northwest Coast Cruise: Summer 2002

The following year UWT chartered the newly completed SSV *Robert C. Seamans* (Figure 3), a ship owned and operated by the Sea Education Association (SEA) of Woods Hole, Massachusetts. The ship, a 134-ft. square-rigged topsail schooner, was completed in 2001 by J.M. Martinac Shipbuilding, a company located within sight of UWT on Commencement Bay, Puget Sound. This was the first tall ship built in Washington in over a decade and the only one built in Tacoma for the sole purpose of providing undergraduate research opportunities at sea. As the *Seamans* was designed explicitly for open ocean work, our cruise track this year stretched for 13 days from Tacoma to San Francisco, California (Figure 4). UWT arranged return travel to Tacoma. Twelve students, one professor from Highline Community College, and two professors from UWT were onboard, in addition to the SEA crew. No prior sailing experience was required.

The *Seamans* was designed for oceanographic research, and therefore was well equipped with oceanographic instrumentation and laboratory space. The ship includes a wet lab and a dry lab, as well as a combination library and student computer room. A hydraulic winch is used for CTD (SBE 19) and bottle rosette deployment, although this system does not include a real-time data cable as on the *Barnes*. The CTD on the *Seamans* is a basic model with no additional sensors attached. This ship is also equipped with an acoustic Doppler current profiler (ADCP), CHIRP bathymetric profiling system, and a continuous flow-through system measuring surface temperature, salinity, and raw fluorescence. Oxygen determination was carried out in the lab by traditional Winkler titrations using a buret, and nutrient samples (nitrate, phosphate, and silica) were prepared via standard oceanographic manual methods and measured using a fiber-optic spectrophotometer (Ocean Optics Chem2000). Biological productivity was determined by measuring unfiltered whole cell pigment extractions (i.e. no sonication or centrifugation) in a fluorometer. In addition, gross estimates of community diversity were determined for neuston, zooplankton, and phytoplankton samples by family-level frequency counts under dissecting or compound microscope using subsamples of 25-100 organisms.

For the duration of the cruise, students were divided into three watches that rotated duties on a 24-hour schedule having 5 shifts (7am-1pm; 1pm-7pm; 7pm-11pm; 11pm-3am; and 3am-7am). Therefore, each watch rotated through all shifts every three days before repeating. Watches took turns sailing the ship, collecting oceanographic data and samples, analyzing samples, and performing other shipboard chores. Because the watch schedule reduced interaction between groups to very short intervals, it was decided to create watches that would be self-sufficient research groups as well. Subsequently, the three professors were also assigned primary responsibility for a particular student group. Although the original intention was for professors to be able to “float” from watch to watch, this occurred very infrequently due to sleep schedules and the necessity for professors to participate in sailing and other ship duties on a short-handed cruise.

Lessons Learned and Model Comparisons

On the whole, student feedback from both years has been overwhelmingly positive. Course evaluations have been high and students continue to speak fondly of their experiences. One student called the course "…an incredible intellectual experience," and another said "…the total experience was one I will take with me for a lifetime." This is evidence of the impact that intensive scientific field experiences have on undergraduate learning. Non-science and science students alike are amazed at the amount of knowledge they mastered in a relatively short time, and student research projects usually exceeded our expectations. Looking back on the two years we have offered this course, we have been able to extract several key insights regarding course design and the resulting learning outcomes.

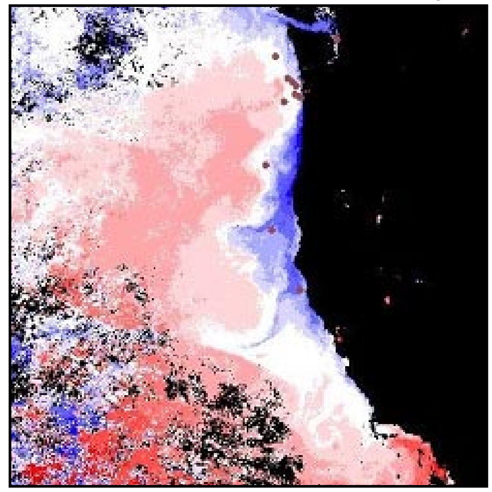

Figure 4. Sampling stations for the 2002 cruise. The cruise track begins in Puget Sound and follows the Pacific coast from Cape Flattery to San Francisco Bay, with extensive sampling near the mouth of the Columbia River.

Minimizing Costs

Total fees per student for the summer course, not including tuition, were $1700 in 2001, whereas the cost per student in 2002 was $2800. However, the cruises ran for different lengths of time, so a more accurate comparison is cost per student per day: $243/student/day in 2001 and $215/student/day in 2002. In addition, expenses were partially subsidized in 2001 by the organization that cancelled our original contract, so without this aid costs would have been greater than $315/student/day the first year, approximately $100 more than in 2002. This discrepancy between the two years can be attributed largely to the capacity of each vessel. The charter cost for the *Seamans* per day is roughly twice that of the *Barnes*, but the *Seamans* can accommodate over 20 students, whereas the *Barnes* is overtaxed with just seven. Therefore, there is definitely an economy of scale that is important to consider when setting up a course like this. It is more economically feasible to offer a field experience at sea if a larger number of students can be recruited for a bigger research vessel. Thus, to better ensure that we have a large enough number of students for recruiting to fill a 20-person research cruise, the most frequently we can offer this course is every other year.

Recruiting Students

In addition, to further expand this pool we have also made attempts to recruit students from local community colleges, other four-year universities and colleges in the region, as well as the other campuses of the University of Washington. Although this sounds simple enough, we have learned that there are numerous roadblocks to recruiting students from other institutions, regardless of how close they are. Even intra-university recruiting is difficult across campuses. Problems include the general lack of a central advertising platform for off-campus opportunities, difficulties related to the conversion of academic course credits from one place to another, the need for word-of-mouth promotion of the course by faculty, and a general negative perception regarding the academic rigor of offerings at another institution.

The timeline for advertising the course and recruiting students is also very important, especially for non-traditional students such as ours at UWT. Based on the number of inquiries we have received both years we have offered this course, and even this past year when we have not, a large number of students are very excited about the prospect of participating in intensive learning experiences. However, in the past we have lost many of those interested for two primary reasons: the cost of the course and the time required for the field component.

For non-traditional students with families and other financial burdens, it is imperative to provide assistance in finding the means of paying for a course like this. The cost of the course has been minimized to the extent possible, but nonetheless financial planning has been important for almost all of our participants. The longer the students are given to plan for the expenses of such a course the better. Students may be eligible for financial aid, not only for course tuition but also for the course fees, but the paperwork requires time to be approved. Many aid providers also require a breakdown of course fees prior to approval. For those not eligible for financial aid, commitment to this course means planning far enough in advance to save up the money or to request a non-academic loan.

The time commitment for this course is not trivial for non-traditional students. With families and work schedules, as well as other academic constraints, students need a lot of lead-time to be able to organize their lives around the course. The length of the field component is also an important consideration for our students. For many, due to work vacation limitations and the need for childcare, two weeks is the maximum possible time they can feasibly devote to being away from home.

Therefore, to make the course as accessible as possible to the large majority of non-traditional students, we recommend: (1) advertising the course at least 9-12 months in advance; (2) providing as much financial planning assistance as possible; (3) limiting the field component to two weeks or less; and (4) constraining the course as best as possible within the regularly scheduled academic calendar. Monetary and time considerations are the primary reasons that other existing undergraduate oceanographic research opportunities (e.g. SEA's Sea Semester) are inaccessible to non-traditional students. Therefore, courses such as ours often provide the only opportunity for many undergraduates to participate in field-based experiential learning in oceanography.

Onboard Collection of Quality Data

The primary goal of undergraduate research opportunities is to make the students realize that they can be scientists too. Students often view scientific research as something that they are not capable of doing. They are disconnected from the scientists' realm and only read about research in papers or textbooks. Therefore, by immersing students in the real job of designing sampling plans, collecting and analyzing samples, and interpreting and presenting their results, we allow students to contribute meaningfully to the scientific knowledge base and endow them with a sense of ownership with respect to their own scientific research. Through this, they gain confidence in their own capabilities and start to feel like scientists themselves.

For this to occur, however, requires that the data they collect and the results they produce are of good quality and based on sound scientific principles. Too often students carry out the motions of scientific research without being able to verify that what they are producing means anything outside of the classroom. Therefore, two things are required for students to have confidence in the data they collect: (1) good data quality assurance practices and (2) the ability to compare their data to previously published results.

Although data quality could be ensured by sending samples to a commercial laboratory for analysis, this would do little for advancing student learning or promoting a sense of ownership. In addition, the timing of the course requires that most, if not all, sample analyses be performed onboard during the cruise. Another important consideration is the degree to which chemical and biological measurements are performed manually versus an automated method. Manual methods provide students with a better understanding of analytical techniques but require more time. Increased analysis time decreases the number of samples that can be collected, as well as reducing downtime that could be used for data interpretation and discussion. Therefore, there are inherent trade-offs in the selection of analytical methods. As a result of the differences between the two cruises, we are in a position to make some recommendations regarding the choice of instrumentation and methods.

Nutrients

Nutrient measurements are incredibly time consuming and difficult to perform at sea, but also integral to an understanding of biological productivity and marine chemistry. The standard method used by most oceanographers, utilizing a nutrient autoanalyzer, is too expensive and complex for student use. Instead, we used manual wet chemistry methods using pre-prepared chemicals and a field spectrophotometer from Hach Co. one year, and standard manual nutrient methods (Grasshoff *et al.* 1999) with a fiber-optic spectrophotometer from Ocean Optics Inc. the second year. To assess the viability of both of these methods, duplicate samples were collected, preserved, and analyzed by the UW Marine Chemistry Lab after the cruise (using a Technicon AutoAnalyzer II) and compared to student data. Nitrate results are used as an example of this comparison (Figure 5).

We found that Hach methods, although designed for ease of use, have several flaws. First, dry chemicals are much more difficult to deal with on a moving vessel, and working with dry cadmium powder creates a significant chemical hazard. Second, results for all nutrients using Hach methods showed poor precision and accuracy when compared to UW Marine Chemistry Lab results. Finally, ongoing problems with the manufacturer's flow-through system caused erratic measurements interspersed with good results, requiring constant instrument maintenance. On the other hand, using a homemade, gravity-driven cadmium reduction column and the Ocean Optics spectrophotometer for nitrate, good agreement between student data and commercial data was achieved. Good data quality for phosphate and silica was also achieved using standard manual methods onboard.

Overall, we have found that onboard student nutrient analysis is feasible in the time available and can produce good quality results. In addition, using standard manual analytical methods adds to student understanding of the chemistry

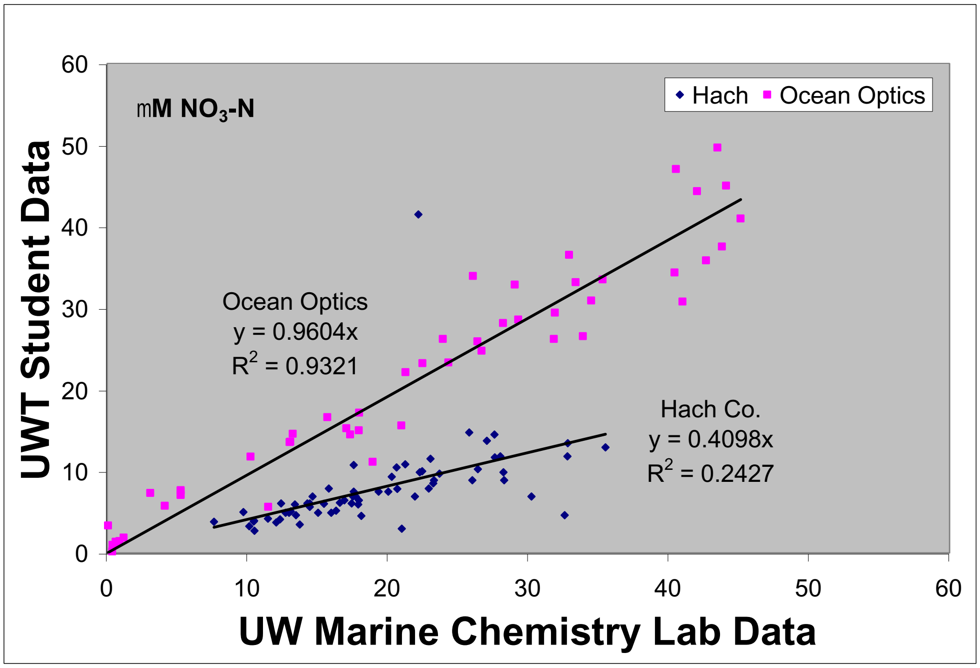

Figure 5: Comparison of nitrate concentrations analyzed by students at sea (y-axis) and results for duplicate samples analyzed by the UW Marine Chemistry Lab (x-axis). Hach Co. chemicals and methods were used in 2001, and standard manual methods (Grasshoff et al. 1999) were employed in 2002 using a Ocean Optics spectrophotometer.

involved and the good laboratory practices required for acceptable data quality. As a final point, nitrate measurements are the most time-consuming owing to the need for a reduction column and the difficulty in bringing multiple columns into a cramped shipboard laboratory. Thus, in the future we will convert from a gravity-fed column to a pump-driven system to decrease analysis time to the extent possible using this method.

Dissolved Oxygen

Oxygen concentrations were determined by three different methods over the two years this course was offered. On the *Barnes* the inclusion of a real-time oxygen probe on the CTD made it possible to examine small-scale oxygen patterns in the vertical profile and to then collect water samples at those depths. This real-time capability creates numerous "teachable moments" that can then be reinforced by allowing students to set the depths for sample collection. Although probes are notorious for potential accuracy problems, concentrations in this continuous profile can then be verified by students using Winkler titrations onboard. Consistent results are obtained using either a buret or an autotitrator, but the latter results in a much shorter analysis time, allowing the students to accomplish more. As both techniques are essentially the same, students do not learn anything more from using a buret. Therefore, in order to maximize student learning, a real-time data cable and oxygen probe are recommended components of the CTD, while an autotitrator is a great time-saver in the lab.

Biological Productivity

The value of a real-time CTD connection is again reinforced by the inclusion of a fluorometer. Similar to oxygen, the immediate visualization of biological data increases student excitement during data collection and allows the meaningful targeting of specific depths for water sample analyses. This can then also be used to establish depths for plankton sampling, creating a cause-and-effect relationship to be formulated by students and fortifying the logic behind sampling design. The continuous profile then provides the basis for laboratory measurements of biological productivity and relative species abundance.

For students to be able to compare their results to published data, it is usually necessary to measure chlorophyll concentrations in water samples. Although there are several steps in the analysis of chlorophyll, we have found that students are easily capable of following the standard protocol, and actually enjoy the opportunity to use the different lab apparatuses. Multi-port vacuum manifolds and a sonicator bath make it possible to batch process samples, and therefore save time. In our view, onboard raw fluorescence determinations are much less desirable because they produce simplistic profiles, require valuable student lab time, are not directly comparable to published data, and do not provide the same learning excitement as real-time data collection. Therefore, a real-time fluorometer is a recommended addition for the CTD, and if shipboard analysis is to be included, full chlorophyll determination is worthwhile.

With regard to determining relative species abundance, it should be realized that little can actually be accomplished onboard a moving vessel. Species-level taxonomy is too complex for an introductory course, requires an enormous amount of time, and usually requires the use of a compound microscope—probably the fastest way to get all the students seasick. In general, more easily discernible classifications must be used—i.e. centric diatom, pennate diatom, dinoflagellate, etc. Even then plankton counting can quickly become the bottleneck in data analysis. Therefore, the most appropriate method for students at sea is to count a subsample of 50 organisms from a concentrated plankton sample to determine relative abundance. Even then, the number of samples analyzed should be kept to a minimum to allow time for other work. This still allows students to make comparisons between plankton types in different locations. In addition, plankton samples can also be preserved and then analyzed more in-depth in the lab as the basis for another undergraduate research project apart from the course.

Other Data Appropriate for Shipboard Learning

In addition to the data discussed above, we have also experimented with others, some of which we found useful for students and others we found were not. Sediment samples were useful for demonstration purposes only. We have been able to show students examples of benthic invertebrates, but any systematic analysis of sediments is constrained by the time required to acquire samples (which usually requires switching between the CTD and the dredge) and the difficulty in processing sediments at sea. In addition, deep ocean sampling requires significant cable time and length. Underway measurements such as the flow-through seawater system, current measurement using the ADCP, and bottom and sub-bottom profiling systems are useful to help the students visualize the big picture. Although the physics involved in ADCP data collection may be difficult to explain, the graphical results are beneficial for student understanding of tidal mixing, upwelling, diurnal plankton migration, and general ocean circulation. For our cruise aboard the *Seamans*, this data helped students visualize concepts that had been discussed in lecture and provided a physical basis for the chemical and biological results collected. The *Barnes* has subsequently been retrofitted with an ADCP of its own. The CHIRP system, on the other hand, is too complex for student use without significant instruction, and could easily be replaced with a continuous depth profile provided by the ships sonar system.

The Most Important Course Design Considerations

Group formation and size turned out to be critical factors both years. Although a few onboard interpersonal squabbles resulted as a result of instructor-created groups, confrontations were few and did not seem to unduly color the positive aspects of the cruise. The importance of evenly distributing the level of science background and other student skills among groups only became evident at the end of the cruise when students began to synthesize and interpret their data. Two valuable lessons regarding group dynamics were garnered from our experiences. First, good leadership was the overriding factor in producing a quality group project, much more so than science background. The organization of group work by student leaders (self-selected) enabled groups with minimal science background to produce amazing results, whereas other groups with extensive science background floundered without leadership. Second, each year one or more students "disappeared" once on shore. This made group size important, as the remaining students had to fill in the gaps. This seems to become more of a problem the more enticing the trip itself becomes. In other words, some students participate solely for the allure of the voyage and not for the education, and at the end of the trip they forfeit their grade and leave other group members to produce the final project. Therefore, groups should always comprise at least three students, and non-academic characteristics of group members should be considered carefully by instructors for group formation.

However, the single most important lesson learned in our two years of experience is to allow sufficient structured class time at the end of the cruise for the completion of student projects. A consistent complaint from students both years was that there was not enough time to complete their work. Three factors contribute to this problem: (1) the shortness of the research cruise; (2) the lack of scheduled class time at the end of the cruise; and (3) constraints imposed by the summer academic calendar.

The most opportune time for completing student projects would be onboard ship. Their attention is still focused on the task at hand, there are limited outside distractions, and you aren't faced with the disappearance of students. However, it is difficult as it is to collect sufficient data for group projects in the short time at sea, and extending the cruise means higher costs and less student participation. In addition, having the discipline to sit inside and write is difficult for students also wanting to enjoy the remaining voyage. Therefore, in reality the cruise would have to be much longer to be able to collect sufficient data and to allow the novelty of being at sea to wear off so that students would focus on writing. Considering financial and time constraints of our students, this is not a viable option.

Adding to student difficulties with completing their projects on time is the fact that once off the ship, their other time commitments begin to take precedence, especially after being gone for one to two weeks. Both years we have left the course schedule open between the end of the cruise and the date for project presentations, allowing students to create their own schedules for working on their projects. This has turned out to be a bad idea, particularly since students have a relatively tight deadline to meet. Faced with a relatively rigid academic calendar, an obvious answer to this dilemma would be to schedule structured class time following the cruise. This would force students to appear, and would dispense with students having to provide motivation and scheduling for their own group.

Conclusions: *Barnes* vs. *Seamans*

Having now considered the various course design aspects for both years, which design works for student learning? The answer is both. The *Barnes* cruise allowed students to focus solely on science, allowing them to acquire an incredible amount of knowledge in a week's time. The Puget Sound region offers wonderful oceanographic variation, while the short distances involved made it possible to collect an enormous amount of data in a short time. In addition, docking or mooring each night allowed extra downtime for group discussions, catching up with sample analysis, or getting off the boat and relaxing in town. Student disappointment engendered after the cancellation of the original cruise this year was offset by an intensive learning experience in the local, and yet really unexplored waters of their own region. Finally, the absence of all other people (with the exception of the captain and mate) made this cruise a much more intimate experience for all involved.

Interestingly, we were able to collect much more data onboard the *Barnes* than the *Seamans*. This is due primarily to the time spent sailing the *Seamans*. However, the *Seamans* experience really approaches student learning from a much broader perspective. Although many would suggest that time spent sailing does nothing for advancing scientific knowledge, our experience has led us to a different conclusion. In the process of learning how to sail a tall ship, students gained confidence in their own previously untested abilities. This confidence was then transferred to the research they were conducting as well. A palpable change took place when they began to handle the ship themselves, and they began to show greater interest in the science they were conducting. In addition, the experience aboard the *Seamans* set these students far apart from other undergraduates, engendering a strong sense of ownership of the things they accomplished.

Although there are positive and negative aspects related to both the 2001 and the 2002 "Research at Sea" courses, both were solid successes. This experience has reinforced our belief that field-based intensive research is invaluable for advancing student learning and creating the excitement needed to recruit and retain promising undergraduates in the sciences. Therefore, we will continue to investigate ways to offer such opportunities to UWT students in the future.

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